Finite-size scaling for non-linear rheology of fluids confined in a small space(Poster session 1, New Frontiers in Colloidal Physics : A Bridge between Micro- and Macroscopic Concepts in Soft Matter)

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Finite-size scaling for non-linear rheology of fluids confined in a small space

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分子動力学法により、小さな系に閉じ込めた流体のレオロジー特性のサイズ依存性を調べた。有限サイズスケーリングを行う事により、粒子のダイナミクスの相関長とシステムサイズの拮抗が原因となって、レオロジー特性の変化が起こる事を示した。[1]

1 Introduction

The rheological property of fluids confined in a small system differs from that in the bulk. When the size of the system becomes small, the fluid exhibits the increase of the viscosity, shear-thinning and the appearance of the yield stress as well as the slowing down of the dynamics [2].

This transition of the rheological property of the fluids in a small system is similar to that of glassy materials. Glassy materials, such as dense colloidal suspensions and super-cooled liquids, also displays the increase of the viscosity, shear-thinning and the appearance of the yield stress as well as the slowing down of the dynamics as the temperature decreases or the density increases. From this similarity, the rheological transition by the reduction of the system size is considered as the glass transition by the confinement of the fluid in a small system.

In glassy materials, it is observed that a dynamical correlation length that characterizes the distance over which particle motion is correlated grows. Near the glass transition point, the dynamical correlation length becomes comparable with the system size [3]. Considering the similarity between fluids in a small system and the glassy material, the dynamical correlation length seems comparable with the system size also in fluids of small size. From this fact, we conjecture that there is a mechanism of the rheological transition by the competition between the correlation length of the dynamics and the system size by the reduction of the system size.

2 Result

In order to check whether the rheological transition occurs by the conjectured mechanism, we investigate the system-size dependence of the rheological property by molecular dynamics sim-

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ulations. From this simulation, as shown in the figures, we find that the viscosity is scaled as [1]

$$\eta(T,\gamma,L) = \eta_0(T,L)G\left(\gamma\cdot\eta_0(T,L)^{\frac{3}{2}}\right), \tag{1}$$

$$\eta_0(T,L) = \eta_I(T)H(\xi(T)/L), \tag{2}$$

where $\eta_0(T,L) = \lim_{\gamma\to 0}\eta(T,\gamma,L)$, T is the temperature, L is the system size, γ is the shear rate, $\xi(T)$ is the correlation length of the dynamics, $G(x)$ is the function which has the property as $\lim_{x\to 0}G(x) = 1$, $\lim_{x\to\infty}G(x)\sim x^{-\frac{2}{3}}$, and $H(x)$ is the function which has the properties as $\lim_{x\to 0}H(x) = 1$. From this scaling functions, it is concluded that the strong size dependence of the rheological property is caused by the competition between the correlation length and the size of the system.

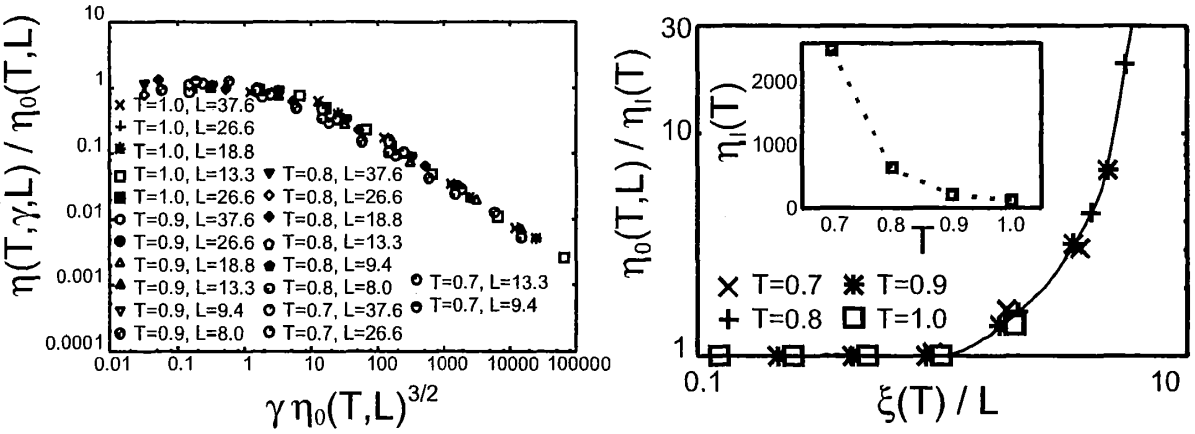

Figure 1: left : $\eta(T,\gamma,L)/\eta_0(T,L)$ as a function of $\gamma\cdot\eta_0(T,L)^{3/2}$. The data are at $T = 0.8, 0.9, 1.0$ and $L = 9.4, 18.8, 37.6$. right : $\eta_0(T,L)/\eta_I(T)$ as a function of $\xi_4(T)/L$.

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